

Model Hingeless Rotor Dynamics Program

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A wind tunnel experiment was conducted to measure the aeroelastic stability of a soft in-plane hingeless rotor with swept-tip blades. The data from this experiment will be used to assess current helicopter analytical tools and to guide future improvements to these codes. Aeroelastic and aeromechanical stability are important elements in the design of helicopters. Poor design, in this regard, can lead to the loss of prototype aircraft and loads problems, and can limit cyclic annoyances. For this reason it is important for helicopter designers to have analytical tools that accurately predict such phenomena.

The development of accurate analytical methods requires careful comparison of calculations with experimental measurements. These methods, particularly at an early stage in their development, benefit

from test data obtained with simplified rotor models whose properties are accurately characterized. Two such tests have been completed at Ames Research Center. The first test, completed in 1995, was conducted using a rotor with straight blades. The second test was completed in 1999 using a rotor with swept-tip blades. The swept-tip geometry introduces additional bending/torsion coupling and provides data that amplify the importance of the air loading at the tip of the blade. Both types of rotor blades and the swept-tip rotor installed in the wind tunnel are shown in figure 1. Stability of the lag mode is measured by exciting this mode and measuring the decay with the Moving-Block analysis after the excitation is terminated. The excitation is achieved by oscillating the blades root pitch at the regressive lag frequency by using hydraulic actuators in the nonrotating system. Both rotors were tested over a range of forward flight conditions on an essentially rigid test stand in one of the Ames 7- by 10-Foot Wind Tunnels.



Fig. 1. Isolated rotor aeroelastic stability model with swept-tip rotor in the Army/NASA 7- by 10- Foot Wind Tunnel; straight and swept-tip rotor blades.

In addition to the wind tunnel test, calculations were made with a comprehensive rotorcraft analytical tool, CAMRAD II, to demonstrate current analytical capability. The second figure shows damping measurements of the regressing lag mode for the swept-tip rotor and CAMRAD II calculations. In the figure the damping coefficient, or exponent, is plotted versus the advance ratio (a measure of airspeed, $\mu = V/WR$) for five collective pitch angles. The agreement between analysis and experiment is good for the lowest collective pitch angles; however, the analysis overpredicts damping as the collective pitch angle is increased. Further, the calculations do not capture the up-down-up character of the measurements with increasing advance ratio. An analytical study has been initiated to look at the sensitivity of damping to various physical model parameters and analytical model sophistication.

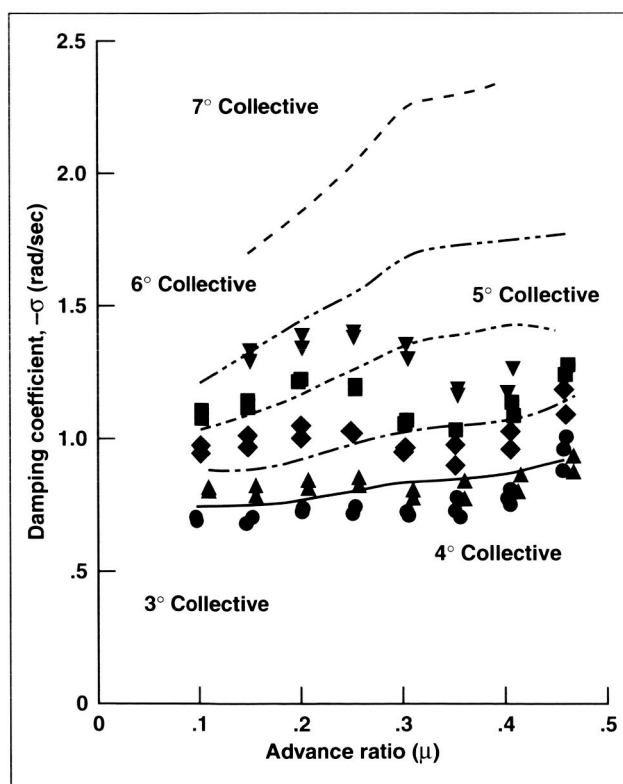


Fig. 2. A comparison of theory and experiment for the swept-tip rotor regressing lag mode stability in forward flight for various collective pitch angles.

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Active Control of Stall on Helicopter Rotors

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In an effort to expand helicopter flight envelopes, this analytical study explores the potential of using higher harmonic blade pitch to reduce the adverse effects of dynamic stall on rotor blades. Since excessive stall-induced loads can damage rotor structural components, stall severely restricts helicopter maximum speed and loading capabilities. On the other hand, successful control of stall can enhance the utility of helicopters.

The rotorcraft analysis code UMARC (University of Maryland Advanced Rotorcraft Code) was modified for a stall suppression investigation of the UH-60A rotor. At a severe stalled condition, the analysis predicts three distinct stall events spreading over the retreating side of the rotor disk. Prescribed 2-per-rev input can reduce stall moderately, as shown in the figure, where the lift excess is used as a measure of stall; the other input harmonics are less effective. Stall responses to individual input harmonics exhibit highly nonlinear behaviors, rendering the closed-loop controller ineffective in suppressing stall and the combined effects of individual harmonics non-additive.

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